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NATIONAL ACADEMY OF SCIENCES

Number 3 • September 1957

IGY BULLETIN

A monthly survey by the U. S. National Committee for the International Geophysical Year. Established by and part of the National Academy of Sciences, the Committee is responsible for the U. S. International Geophysical Year program in which several hundred American scientists are participating and many public and private institutions are cooperating.

Status Report: The Upper Atmosphere Program

STUDIES during the IGY in five closely interrelated areas of scientific inquiry will contribute directly to a better understanding of high atmosphere conditions, behavior, and influence upon man's more immediate environment. Knowledge gained from investigations in any one of the disciplines of solar activity, cosmic rays, geomagnetism, ionospheric physics, and aurora and airglow can often be applied directly to explain phenomena in one or more of the others.

The influence of the sun in the high atmosphere is of central importance. Radiation from the quiet sun is responsible for the ionospheric layers and controls many chemical processes in the upper atmosphere. Disturbed solar conditions, however, directly affect radio communication via the ionosphere, and often cause unusual auroral, geomagnetic, and cosmic ray activity.

In this issue of the *Bulletin*, one section is devoted to the US-IGY program in each of the upper atmosphere disciplines, and there is a final section which reviews related experiments in the rocketry program.

The section on solar activity includes reports on the status of flare patrol projects, coronal observations, and mapping of the sun's magnetic fields.

The cosmic ray section reports the status of projects directed at the study of cosmic ray intensity, charge, and mass, including extensive high altitude balloon experiments. Preliminary findings are described.

The report on the geomagnetism program covers projects concerned with the recording of magnetic storm effects, measurement of space gradients of magnetic field disturbances, any relationships between meteorological and geomagnetic effects, studies of the postulated equatorial and northern geomagnetic upper atmosphere currents, recording of the fine detail of magnetic fluctuations, as well as widespread absolute measurements of the earth's field.

In ionospheric physics, the report describes IGY work in vertical incidence soundings, radio noise, ionospheric drifts, absorption, back scatter, sporadic E ionization, forward scatter and whistlers.

The section on aurora and airglow reports the status of programs utilizing the all-sky camera, volunteer visual observation, the use of patrol spectrographs and scanning spectrometers, the measurement of ionospheric absorption in auroral zones, and the recording of airglow intensity and spectral distribution.

The final section contains a summary report of preliminary experiment results of upper atmosphere probing by rockets.

Solar Activity Program

Variations of the sun's activity have been known from the earliest years of application of the telescope. Galileo's sunspot drawings made in 1612 are comparable in quality with drawings made today with small modern telescopes. A vast number of phenomena of the sun, in addition to sunspots, evince variations of one time scale or another.

No one today disputes that certain of the sun's changes are directly related to responses found in the earth's atmosphere. There are also many other suspected sun-earth relationships, the existence or importance of which is the subject of considerable discussion.

For the purposes of the IGY, there are three principal goals to be served by solar astronomers in their study of the sun's activity. They seek (1) to warn of the times of expected geophysical effects of solar activity; (2) to make comprehensive physical measurements of all possible solar phenomena accessible to their observing instruments; and (3) to use the observations of these phenomena, making appeal to theoretical knowledge, to provide a complete post-event assessment of the time variations of the invisible forms of solar emission, many of which, though not directly accessible to measurement, may be expected to have important geophysical effects.

The US-IGY program in solar activity involves the principal solar observatories of the country, plus one newcomer established on a modest scale in Hawaii for the purpose of filling the observational gap in the vast Pacific area. There are now ten sites where special solar observations are being conducted, with important volunteer observations also being made.

Solar flares are probably the most important of all solar phenomena that have well-known effects on the earth, although it should be kept in mind that flares are only one of about ten different solar phenomena which are being carefully observed and reported. As part of the International Flare Patrol, observations at intervals of three minutes or less are being taken at the Naval Research Laboratory (NRL), McMath-Hulbert Observatory, High Altitude Observatory, Sacramento Peak Observatory, Mount Wilson Observatory, and the University of Hawaii Solar Observatory. Two stations are awaiting delivery of high quality Lyot-designed flare patrol instruments built in France; these use birefringent filters of 0.75 A band pass. Three stations are using less elaborate instruments of smaller aperture with German birefringent filters of 0.5 A band pass, and one station is using a spectroheliograph.

Electronic devices designed to detect solar flares by means of their ionospheric effects on cosmic radio noise and atmospheric noise are being installed at High Altitude and Sacramento Peak Observatories. Similar instruments are in operation at McMath-Hulbert Observatory and Renssalaer Polytechnic Institute.

The Sacramento Peak and High Altitude Observatories have extensive programs for observation of several different aspects of the variations of the sun's corona, so important for the formation of solar radio noise, and for the emission of soft X-rays which are absorbed in the ionosphere of the earth.

Solar radio noise, in the meter wavelength region of the spectrum, is being observed at the following locations: NRL; Sacramento Peak Observatory through the Harvard College Observatory Project at Fort Davis, Texas; University of Michigan; National Bureau of Standards (NBS); Cornell University; and the University of Hawaii. Two of these stations will operate radio frequency spectrographs with a wide frequency range.

McMath-Hulbert and High Altitude Observatories are recording the life history of the variations of the width and intensity of spectrum lines of certain major flares.

One of the most interesting and potentially valuable features of the US-IGY program is

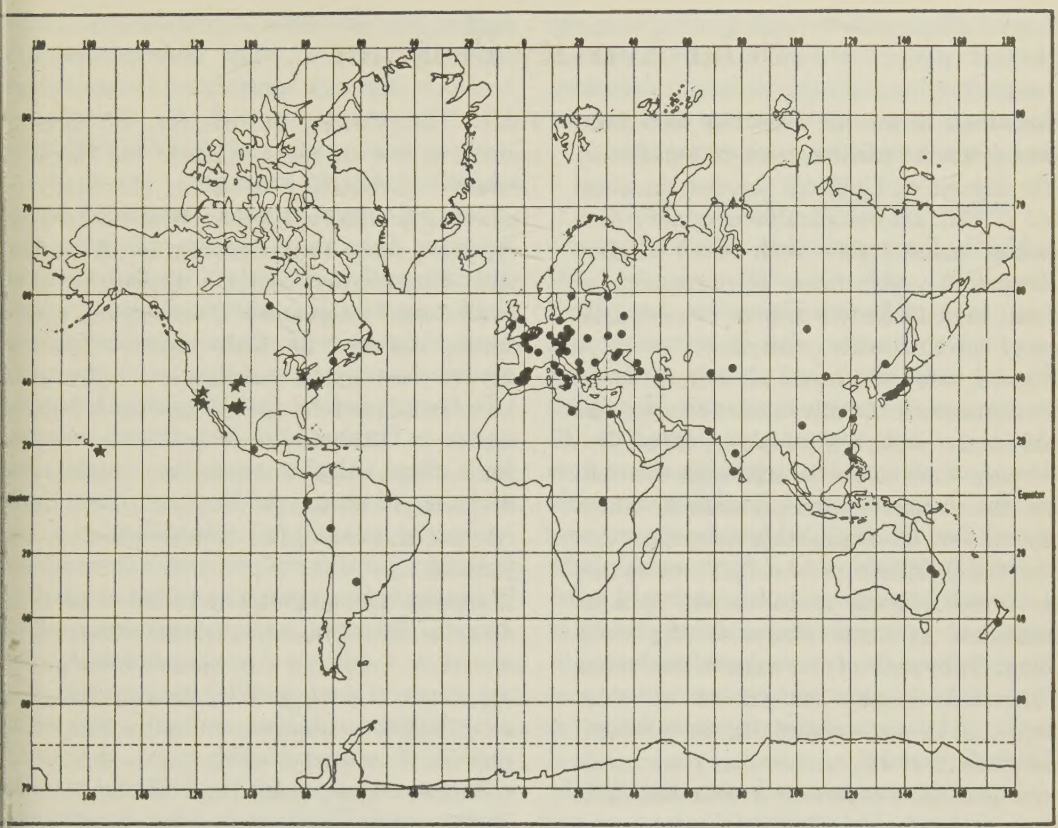

Fig. 1. *IGY Solar Activity Stations. Stars represent U. S. stations; dots represent stations of other countries.*

he effort at Mount Wilson and Palomar Mountain Observatories to map the magnetic eld pattern of the entire solar disk on a day-o-day basis. An instrument which can observe the magnetic field strength distribution, t weak field strengths over the solar disk, as been built by Horace W. and Harold D. Babcock, using the Zeeman effect on spectrum lines from the sun's surface. It seems ighly likely that the surface layer magnetic elds so observed also relate to the magnetic field patterns in the lower atmospheric layers of the sun. These are likely, in turn, to control the emission of electric particles. Thus, it appears very probable that the intercomparisons of the magnetic field data with the patterns of occurrence of auroras, geomagnetic field variations, and ionospheric effects, will yield large returns. The magnetic studies are also very important to the understanding of the emission of cosmic rays from solar flares.

Cosmic Ray Program

In the US-IGY program, nine projects are sing standard neutron monitor or meson elescopes for continuous registration of osmic ray intensity. Eleven projects will make use of balloon flights. Most of these involve experiments to determine the mass and charge spectra of the primary cosmic rays and whether these change with time.

Special efforts will be made to determine the kinds of particles that produce the increase of cosmic ray intensity during zone solar flares, and also to determine changes in the spectrum during world-wide decreases in intensity.

Neutron and Meson Telescope Projects

Martin Pomerantz of the Bartol Research Foundation, with the collaboration of A. E. Sandström of Upsala University, has placed one neutron monitor unit in operation on a Swedish ship which has already made some crossings of the magnetic equator. He reports that the cosmic ray equator located on the first trip represents the largest departure from surface magnetic field measurements observed thus far. By good fortune the voyages of the Swedish ship and a Japanese ship with a neutron monitor installed on board overlapped, and normalization and comparison of the data from the two voyages can be made. Pomerantz is supervising construction of a second neutron monitor for installation at Thule, Greenland.

A neutron monitor had been installed by J. A. Simpson, University of Chicago, on one of the US Navy icebreakers which accompanied the Antarctic expeditions of 1955–1956 and 1956–57. The observations will continue through operation Deep Freeze III. The results showed the discrepancy between geomagnetic and cosmic ray equators which was referred to above.

One of three neutron monitor meson telescope units being constructed under the direction of Robert Brode of the University of California is in operation at Berkeley. Shipment of the second instrument to Hawaii was made in late spring, and the third instrument will be shipped to the Ellsworth Antarctic station in October 1957. The neutron monitor for College, Alaska, constructed under the direction of Serge A. Korff of New York University, is also now in operation.

Robert L. Chasson, of the University of Nebraska is now operating on the campus at Lincoln, Nebraska, a mu meson telescope and a neutron monitor including special arrays for the study of atmospheric, geomagnetic and solar influences on mu and nucleonic components of cosmic radiation.

Meson telescopes for the Wilkes Antarctic Station and Thule have been constructed under the direction of S. F. Singer, Univer-

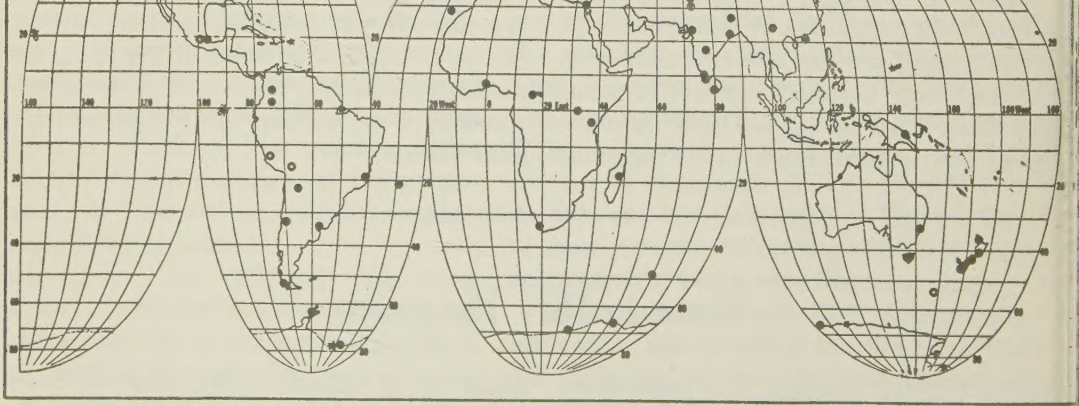

Fig. 2. *IGY Cosmic Ray Stations. Black stars represent U. S. stations; black dots represent stations of other countries; white stars in black circles represent cooperative stations; and black arrows represent balloon launching sites*

sity of Maryland. The telescopes have been shipped to their sites and the Antarctic equipment is now nearly installed.

Balloon Projects

The heavy component of primary cosmic radiation will be investigated by examining photographic emulsions exposed in high altitude balloon flights. The charge of the heavy primaries will be measured by a number of techniques which were used in a series of pre-IGY measurements reported by the project director, W. F. G. Swann of the Bartol Research Foundation. Results of these experiments will be integrated with those from the programs of M. A. Pomerantz of the same institution. He will investigate the correlation of solar activity with high altitude primary cosmic ray intensity through use of balloons carrying various types of charged-particle detectors.

Investigation of the isotopic constitution of cosmic radiation at balloon altitudes will be carried out by Marcel Schein of the University of Chicago. The heavy nuclei component of the primary cosmic radiation will be studied in great detail by exposure of blocks of large size to cosmic radiation at different latitudes. Already, heavy nuclei have been investigated by means of two balloon ascents —in Texas in January 1956 and in Guam in February 1957—by courtesy of ONR as part of its Skyhook balloon program. Techniques were developed for the identification of heavy nuclei, and a preliminary Z spectrum has been obtained from the Texas emulsion stacks. Furthermore, interesting results have been obtained on the breakup processes of heavy nuclei. These results are in reasonably good agreement with fragmentation probabilities of medium heavy elements (C,N,O) obtained in other laboratories. However, as far as the heavy nuclei of Z greater than 12 are concerned, a considerably higher value has been obtained for the fragmentation probabilities than those reported by some leading laboratories.

Under Herman Yagoda, the flux of low energy heavy primary cosmic rays will be studied by exposure of a series of small emulsion blocks carried to high altitude on balloon flights in polar areas. Preliminary control data for such exposures were provided when a stack of emulsions was flown to a peak altitude of 120,000 feet by the US Air Force at geomagnetic latitude 55°N.

Emulsion studies of heavy primary cosmic rays will be made under the direction of J. J. Lord, University of Washington, as a part of the ONR program for balloon flights during the IGY. Heavy cosmic rays of primary nuclei with Z equal to or greater than 10 will be investigated by study of emulsions under the direction of Otis B. Young of Southern Illinois University. Emulsions will be exposed by means of flights in the extreme north and south and at intermediate latitudes.

In a program directed by H. V. Neher, California Institute of Technology, ionization chambers will be flown in a number of simultaneous balloon flights. These will provide information on the latitude effect, fluctuations in the primary radiation at different latitudes, possible asymmetry conditions existing between the poles or poles and equator, and high altitude cosmic ray phenomena at this phase of the solar cycle as compared with other phases. Expeditions are planned to Thule in the summer of 1957, to Thule by ship in the summer of 1958, and to the Antarctic by ship in the fall of 1958. Simultaneous releases will be made from the Thule-bound ship and from Bismarck, N. D., and also from the ship bound for the Antarctic and from New Zealand. All parts of the ionization chambers have been completed, and twenty of them, a sufficient number for the 1957 summer operations, have been assembled. Design of the amplifier unit is proceeding, and a new receiver is being developed which is considerably lighter than the one used previously.

A project for the measurement of composition and intensity of primary cosmic radiations will be carried out under John A. Simpson, Institute of Nuclear Studies, University of Chicago. Proton and heavy particle intensities at the top of the atmos-

phere will be measured as the total intensity changes with time. A special effort will be made to study kinds of particles arriving at times of cosmic ray intensity increases.

Balloon flights will be made at Prince Albert, British Columbia, through the cooperation of D. C. Rose, Chairman, Coordinating Committee, Canadian IGY Program. The US Air Force Office of Scientific Research (AFOSR) is providing support as part of its cosmic ray program.

Counter studies of the spectrum of primary radiation and its time variations will be directed by Serge A. Korff of New York University. By means of high altitude balloon flights the charge and mass spectrum of the primary cosmic radiation will be investigated, particularly at times of solar disturbances. Korff reported earlier that construction of equipment for the summer flights was continuing, that flights would probably be made from an airport near Minneapolis and that flights were being arranged to be as nearly simultaneous as possible with other balloon flights in Texas. A search will be made there for primary neutrons from the sun. Flights will be made just around the 'knee' of the latitude effect during normal times and during periods of solar disturbances. These should yield information on the energy distribution of the incoming particles and especially of neutrons. Plans are under way for flights from Lufkin, Texas.

An experiment to measure as continuously as possible the cosmic ray intensity at the top of the atmosphere at Minneapolis will be directed by E. P. Ney and J. R. Winckler of the University of Minnesota. A special balloon was developed at the University of Minnesota for this experiment. It is capable of carrying a 30-lb payload to 100,000 ft and remaining there for a period of about 24 hours. Equipment on the flights will include a counting device under development and light-weight oriented plates of photographic emulsion. Several types of monitors were considered and built, and several preliminary flights were made using some of the developmental apparatus flown on large, constant-level skyhook balloons.

The preliminary flights with ionization chambers showed a strong latitude effect at constant level so that latitude changes as small as 7 miles can be detected. Winckler has remarked that this suggests an auxiliary use for the IGY flights, namely, to map out cosmic ray grids for the north-central states built up out of E-W, N-S trajectories. Cosmic ray latitude lines could be drawn and the equivalent magnetic pole for cosmic radiation located. The preliminary experiments also showed that fluctuations in the pulse interval in the ionization chamber can be attributed to the heavy nuclei in the primaries, with the possibility of studying fluctuations of heavy nuclei separate from fluctuations of the singly-charged component. The mean ionization per particle and its change with latitude, atmospheric depth, or time can also be observed.

Studies of solar effects on cosmic rays at high altitude in the Arctic will be carried out under the direction of Kinsey A. Anderson of the State University of Iowa. Observations are planned to include the rates of a single Geiger counter, of a vertical counter telescope and of a single scintillation crystal. The differing effects of arriving solar particles on the various counting devices will yield new information about their nature. During January, transistorized scalers of the type to be used in IGY flights were flown in skyhook balloons during an expedition to Guam sponsored by the ONR. The scalers performed well; as a result, 20 such circuits are under construction for the IGY experiments. Assembly of the ionization chambers has begun, and in March an order was placed for 21 polyethylene balloons.

M. F. Kaplon of the University of Rochester will expose a large stack of stripped emulsion on a balloon flight at a latitude near or above the cosmic ray knee and at a residual atmosphere of 8 gm/cm^2 or less for 8 to 16 hours. From the exposed plates,

the proton energy spectrum will be investigated and a search made for deuterium or tritium. The low energy end of the spectrum will also be studied and the interactions of nuclei examined. A study of high-energy cosmic ray interactions will be made as well. A special stack flipper to orient the emulsion properly is under construction. Emulsions will also be flown, probably in Minnesota, as part of a larger stack in collaboration with M. Friedlander of Washington University at St. Louis.

Special Projects

High-speed cosmic ray intensity fluctuations will be investigated at various latitudes during periods of solar activity, particularly solar flares, by S. F. Singer of the University of Maryland. Two trays of cosmic ray counters of large area will be kept in contact. Their outputs will be fed to a coincidence circuit driving a count rate meter. The observations will be made at high altitude at Sacramento Peak, New Mexico, in the Canadian Rockies, and in aircraft.

Measurements of zenith angle dependence will be made under the direction of Nelson M. Duller of the University of Missouri. A telescope and integral energy meson detector will be used to discriminate against mu mesons of energies less than a fixed cut-off energy and to accept all mesons above this energy at various angles. Detection is being attempted by a direct method using a large electromagnet as a momentum spectrometer, and by an indirect method based on the fact that as the energy of a mu meson increases, its probability of producing a large cascade shower (electronic) in a thick lead shield increases. From preliminary data with a simple multiple-coincidence shower detector, Duller has indicated that analysis of the early recorded data seemed tentatively to confirm that the intensity of shower-producing particles appears to increase at zenith angles away from the vertical.

Paul H. Barrett of the University of California will direct a project for the detection of air showers produced by cosmic ray particles with energies in the range 10^{17} -10^{19} electron volts by means of a large area Cerenkov counter consisting of six stations on the Santa Barbara College campus. Four stations are in operation and data are being recorded at the central station on an Esterline-Angus recorder. Final adjustment of receivers and routine checking procedures are still to be worked out.

Studies of the semi-diurnal planetary variation of atmospheric pressure will be made by operating two pieces of counter-tube recording equipment at high altitude at the laboratory at Chacaltaya, Bolivia, under the direction of Victor H. Regener of the University of New Mexico. Present plans are for operations to begin before 1958.

Finally, Leticia del Rosario of the University of Puerto Rico will measure the sudden increase and slow decrease in cosmic ray intensity at the time of solar flares and attempt to correlate the results with similar measurements taken with neutron counters. Installation of equipment for these special projects should now be complete.

Geomagnetism Program

The magnetic field of the earth, which has been used in surveying and navigation for several centuries, has been under continuous routine observation for more than one hundred years by magnetic observatories distributed over the earth. At the present time there are more than 80 such observatories maintained by various countries.

While the magnetic field is for the most part stable and unchanging over long

periods, the field does undergo some variations. These may be slow, measured in years, or rapid, measured in days, hours, minutes, and seconds. The variations, although they involve large amounts of energy (they envelop the entire earth), rarely amount to more than about two percent of the earth's field and are seldom large enough to disturb a mariner's compass. Mathematical analysis has shown that the permanent field and the very slow variations are due to magnetic effects in the interior of the earth's crust and that the more rapid fluctuations arise from influences external to the earth—in the upper atmosphere or even higher.

During the IGY, many of the US geomagnetic observatories will make absolute measurements of the earth's field. This information is valuable for studying secular or long time variations and for preparing magnetic maps for navigational purposes. The major part of the US program, however, is devoted to experiments designed to yield information about the disturbances, or magnetic storms. The disturbances are known to appear sometimes only in polar latitudes with no effect at the equator, and sometimes simultaneously over the entire earth; fluctuations at the equator with no effects at the poles are never observed.

The fact that the magnetic disturbances increase and decrease with sunspot number is considered adequate proof, and indeed at present the only proof, that they are the result of bursts of radiation of some sort from the sun. The type of radiation is not known, but charged particles, ultraviolet light, and X-rays have been suggested. The manner in which the bursts might cause the magnetic disturbances has been treated in several theories, but none is considered completely successful.

World-wide analysis shows that the main features of the magnetic disturbances are such as would be caused by three great electric currents, measured in hundreds of thousands of amperes, in the upper atmosphere. These three currents are in the zones of maximum auroral frequency in the north and south polar regions and around the earth above the magnetic equator. The latter current appears to have an extraordinary belt of greatly increased intensity concentrated in a narrow width of only about 200 km. The demonstration of the

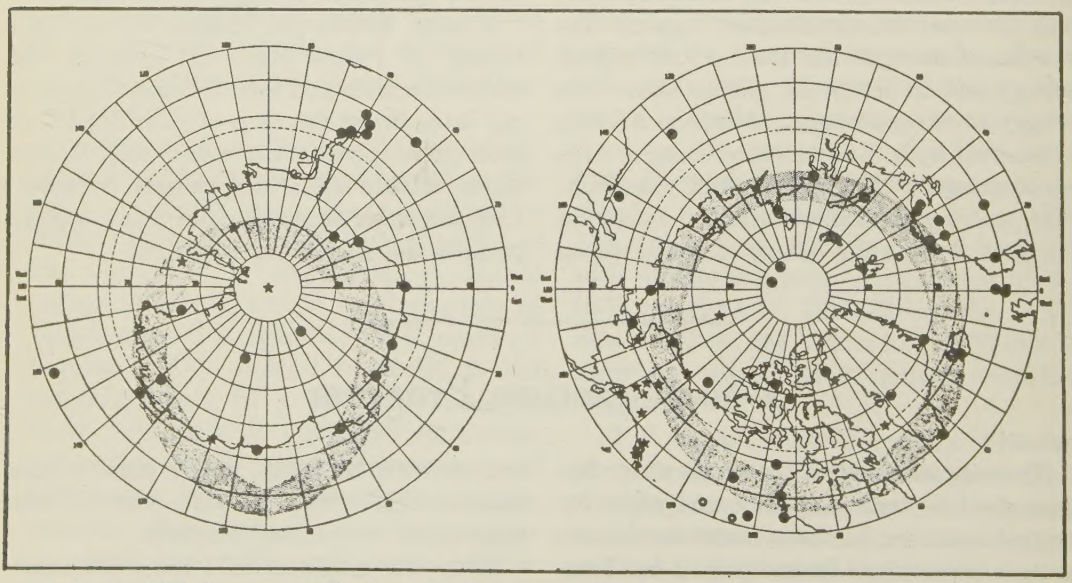

Fig. 3. *IGY Geomagnetic Stations. Black stars represent U. S. stations; black dots represent stations of other countries; and white stars in black circles represent cooperative stations. Stippled bands are zones of maximum auroral frequency.*

existence of these currents, their nature, and their cause is an outstanding problem of geomagnetism.

With a single observatory, only a limited amount of information may be learned about an overhead electric current, whereas much more information may be learned from a network of observatories. For this reason, several networks or chains of stations were established for the US-IGY program.

The US Department of Commerce Coast and Geodetic Survey (C&GS) has in the past operated most magnetic observatories in the United States, under the Division of Geophysics. With a few exceptions, the IGY observatories will also be operated by the C&GS.

In Alaska, in addition to the standard observatories at Pt. Barrow, Sitka, and College, a five-station network is in operation at Anchorage, Barter Island, Ft. Yukon, Kotzebue, and Northway. An instrument is also in operation at Drifting Station A, about 600 miles north of Pt. Barrow.

At College, Alaska, a special instrument designed by J. H. Nelson, of the C&GS, the differential magnetograph, is in operation measuring the space gradients of the magnetic fluctuations. Similar measurements but with standard equipment are now also being made at Healy and Big Delta.

In the United States, an east-west network of five stations, with the main location at Climax, Colorado, and a short north-south arm with two additional stations, are designed to study the overhead currents in detail, and to provide information on any possible connection between meteorological and geomagnetic effects, possibly involving ionized air circulating in wind systems in the lower ionosphere.

In cooperation with Albert Giesecke, Jr., Director of the Huancayo Geophysical Institute in Peru, Scott Forbush of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington is supervising the establishment of a five-station fine-spaced network, centered at Huancayo very near the geomagnetic equator, to study the equatorial current mentioned above.

In the Pacific, the geomagnetic equator passes near the Line Islands in the Eastern Pacific, and the Palau Islands in the Western Pacific. The Scripps Institution of Oceanography, in cooperation with the C&GS, has established geophysical observatories in the Line Islands and has magnetic instruments installed at Jarvis (on the magnetic equator), Palmyra and Fanning Islands. The C&GS is operating the stations at Koror (on the magnetic equator) and Guam.

In a special study of higher frequency variations of the magnetic field, Elwood Maple of the Geophysics Research Directorate (GRD) of the Air Force Cambridge Research Center and A. Raymond Jordan of the Denver Research Institute of the University of Denver, are establishing five stations to record magnetic variations in the frequency range 1–50 cps. These stations at College (now operating), Thule, Cambridge, Denver, and a fifth either in Puerto Rico or Florida, will gather information bearing on the question whether the fluctuations in this band are due to electromagnetic radiation from distant lightning discharges or from induction fields such as those set up by the ionospheric currents overhead.

Rapid-run magnetic instruments have been installed in a number of observatories to study the fine detail of the magnetic fluctuations. The speed of the recorder allows resolution of disturbances of six- to eight-second periods.

In the Antarctic, the magnetic observatories will provide new information on the absolute value of the field and will help map the zone of maximum auroral frequency, known at present only from inadequately spaced observations. Standard magnetic observatories have been put into operation at Little America, Byrd, and Wilkes Stations. Variation instruments only

are in operation at the Pole Station and Cape Adare (in cooperation with New Zealand).

Besides the measurements at land observatories, rockets, and possibly the earth satellite itself, will carry magnetometers up into the regions where the currents are suspected to exist. These experiments may give the ultimate answer as to the existence of the currents and their location.

Ionospheric Physics Program

The heart of the program of ionospheric observations is the use of sweep-frequency sounders to transmit pulses vertically and record the reflected echoes from the ionosphere in the form of ionograms. The United States soundings network has been expanded for the IGY by the Central Radio Propagation Laboratory (CRPL) of NBS and by the US Army Signal Corps Radio Propagation Agency (SCRPA). There are six stations in the Antarctic (one operated jointly with New Zealand), one on the Arctic ice island T-3, and others at Thule, St. Johns (Newfoundland), and Grand Bahama Island along the northern part of the 75°W meridian. Six South American stations have been supplied equipment for the southern extent of 75°W where a closely-spaced network is provided for the study of ionospheric fine structure near the geomagnetic equator. All but five of the planned vertical sounding stations were in operation at the beginning of the IGY, but these will soon be operating since all equipment had been delivered to the sites at that time.

True ionospheric reflection heights can be obtained easily from ionograms only by processing the scaled data with digital computors. For four of the stations (Washington, Panama, and Talara and Huancayo in Peru), this will be performed in the United States at the Pennsylvania State University under the supervision of A. H. Waynick. Test computations have already been carried out.

Ionospheric absorption can be studied by comparing the amplitudes of reflected pulses with those of incident pulses, a technique used at the Pennsylvania State University where the necessary equipment is now in operation. Absorption is also being studied during the IGY by observation of galactic radio noise received through the ionosphere at higher frequencies. This method was developed by C. G. Little of the University of Alaska, and a network of eight auroral zone stations in Alaska, two in Quebec and Sweden, together with a middle latitude network of five stations in the United States, is under his coordination. About two months' delay is expected in installing the stations.

The scintillations of radio stars, as observed from three receivers spaced a mile or two apart on the ground, provide a means of studying ionospheric movements. At the University of Virginia, a station under E. C. Stevenson has begun operations. At the University of Puerto Rico, other ionospheric drift observations have been made for several years by reception of pulsed echoes at three closely-spaced receivers. This program is continuing during the IGY under the direction of Miguel Wiewall. The analysis of ionospheric drift data is difficult, and G. F. Gassmann of GRD will provide additional information by making observations with an airborne ionospheric recorder. The aircraft was to leave for Europe on July 20 and will return at a later date to make flights in the western hemisphere for the study of oblique reflections and atmospheric tides in equatorial regions.

If transmissions are made over radio

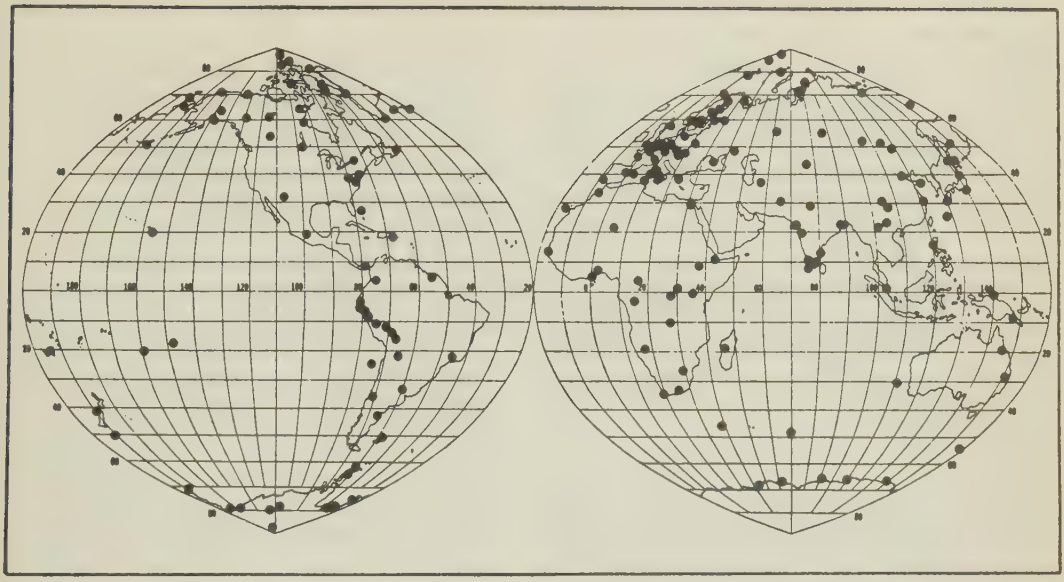

Fig. 4. *IGY Ionospheric Physics—Vertical Incidence Stations.*

propagation paths obliquely incident upon the ionosphere, such as those used for long distance communication, backscatter occurs at the ground beyond the point of ionospheric reflection; it can be observed at the transmitting site with appropriate techniques. From such observations, equivalent vertical incidence properties of the ionosphere can be deduced and meteoric and auroral ionization columns and sporadic ionization can be studied.

In a unique United States program, A. M. Peterson of Stanford University is supervising a network of backscatter stations which cover North America and include two stations in Brazil and Australia. Rotating single-frequency directional antennas will be used to receive the echoes, recording in polar plot (ppi) form at three frequencies. The stations were expected to become operational during July and August. M. G. Morgan of Dartmouth College will supervise sweep frequency backscatter transmissions southward out of the auroral zone from Knob Lake, Canada, beginning in the fall.

Sporadic E ionization at the 100 km level continues to be an enigma. E. K. Smith of CRPL has set up an experiment to verify reports, from Japanese workers, of unusually high reflection coefficients from sporadic E. Transmissions will be sent from Okinawa to the Philippines and Japan, from Panama to Cuba, and from Illinois to Colorado. Stations will not be installed, however, before September 1957.

Forward scattering from the lower ionosphere has been widely studied in the United States and the Arctic. However, no equatorial zone measurements have been made in South America, so CRPL is conducting a pulse experiment there with transmission along and across the geomagnetic equator. The program is under the direction of K. L. Bowles and Robert S. Cohen. The circuits will be operational in the fall.

During the last sunspot maximum, amateur radio hams discovered the phenomenon of transequatorial scatter which is manifested over distances too great to be accounted for by forward scattering from the lower ionosphere. Accordingly, the American Radio Relay League (ARRL) is participating in the IGY through the observation and reporting of two-way contacts by means of transequatorial scatter, sporadic

E clouds, and auroral ionization propagation. The participants are chiefly from North and South America, Europe, Japan and Australia. Wolfgang Pfister of GRD and Mason P. Southworth, ARRL, have organized this program. The data realized from it, together with that from the close-spaced equatorial vertical incidence stations and from the transequatorial forward scatter experiments, should help to confirm or refute a recent suggestion by O. G. Villard of Stanford University as to why transequatorial scatter occurs only during periods of sunspot maxima.

The properties of the ionosphere can be deduced not only by probing it with man-made signals, but also from analysis of the propagation of naturally occurring radio pulses which arise from lightning discharges. In a program expanded for the IGY by CRPL and under the direction of W. Q. Crichlow, fifteen recording stations have been established at locations widely distributed over the earth. They will record radio noise continuously on eight frequencies.

Lightning discharges produce most of their radiated energy at low frequencies which overlap the audio-frequency range. The sferics so produced become 'whistlers' —tones of descending pitch—upon being propagated dispersively over long ionospheric paths because the propagation speed is then a function of frequency. According to a theory of L. R. O. Storey, whistler propagation begins at the point of lightning discharges, follows upwards along the lines of the earth's magnetic field into the far outer atmosphere and returns to the symmetrical point on the earth in the opposite hemisphere.

A pre-IGY whistler experiment, in which simultaneous measurements were made at conjugate locations in the Aleutian Islands and in New Zealand, was carried out by M. G. Morgan of Dartmouth College and G. McK. Allcock of New Zealand. The results bore out the essential details of the Storey theory. As a consequence, the United States, in cooperation with New Zealand, Australia (Macquarie Island), Canada, Denmark (Greenland), Peru, Argentina, and the United Kingdom (Antarctica), is undertaking a very complete study of whistlers in the Western Hemisphere. Morgan has organized the work for thirteen whistler stations in a network in generally eastern US latitudes, including two in the Antarctic. R. A. Helliwell of Stanford University has organized the program for nine stations in a chain of locations in western US latitudes. Sferics locations at some stations will be obtained by radio direction finding. In the North Atlantic, these sferics data will be supplied by the Air Weather Service of the US Air Force, and in the North Pacific by additional equipment at certain of the whistler stations. The investigation of sferics phenomena will also include certain other isolated vlf emissions such as 'hiss' and the 'dawn chorus' which are heard on whistler observing apparatus.

A large proportion of the experimental ionospheric program is operational or nearly so. A considerable amount of data had been taken before the formal opening of the IGY, and it is expected that most stations not yet established will achieve operational status within a short time.

Aurora and Airglow Program

The principle synoptic auroral observational program employs all-sky cameras which photograph the whole sky. The 29 cameras planned for networks in the Arctic, the Antarctic, and the United States have all been constructed and shipped to the field stations. All are not yet in operation, however, for those in northern latitudes will first be employed in September when it becomes dark enough to make observations. These auroral observations are supervised by C. T. Elvey, Director of the Geophysical Institute at the University of Alaska, C. W. Gartlein of Cornell University, and N. J. Oliver of GRD, Air Force Cambridge Research Center.

The final model of the ascaugraph, an instrument for the semi-automatic reduction of all-sky camera films, is under construction. Photographic processing equipment has been installed at College, Alaska, where most of the all-sky camera film will be developed.

Visual observations of auroras by 120 US Weather Bureau Stations and 56 volunteer stations have been in progress for some time. The stations report directly to Gartlein at Ithaca where the data is stored on punched cards for further analysis.

Eighteen patrol spectrographs constructed under the supervision of Joseph W. Chamberlain of Yerkes Observatory, University of Chicago, and N. J. Oliver of GRD for the auroral program have been completed and delivered to the sites as planned. The primary objective of these observations is to establish a profile of spectral changes with latitude in the auroral display and to study auroral variations with time after the display commences. Two of the instruments, together with all-sky cameras, were functioning at Yerkes Observatory and Shingleton, Michigan, during the very intense auroral display of March 2, 1957. Four scanning spectrometers, which are to provide information on rapid changes in the auroral spectrum during auroral displays, have also been constructed. Two of the instruments have been shipped, one to Yerkes Observatory, and the other to the Geophysical Institute of the University of

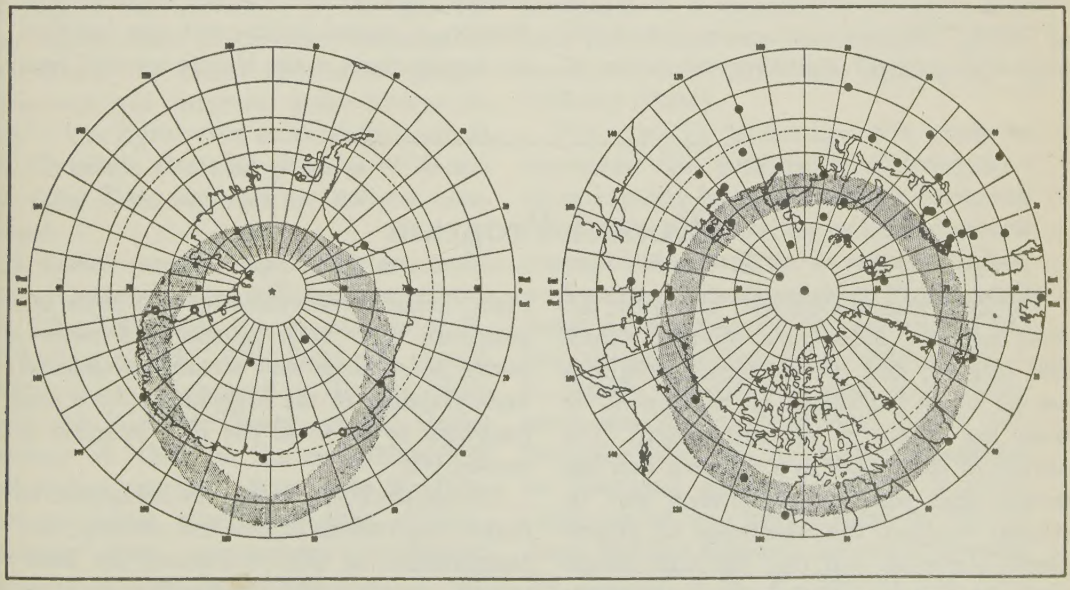

Fig. 5. *IGY Aurora All-Sky Camera Stations. Black stars represent U. S. stations; black dots represent stations of other countries; and white stars in black circles represent cooperative stations. Stippled bands are zones of maximum auroral frequency.*

Alaska. One of the remaining instruments is planned for operation in Little America and the other for operation aboard an aircraft operated by GRD.

A prototype unit has been built for the auroral radar program and has been tested over a period of several months. The remaining nine units for stations in Alaska, the United States, and Macquarie Island are now under construction; installation of most of the units were to be completed prior to September 1957, making it possible to operate through the September equinoctial period, a maximum of auroral activity.

The measurement of ionospheric absorption in auroral regions by observation of cosmic noise is to be performed on an instrument called the riometer designed at the Geophysical Institute, University of Alaska. The program is a joint undertaking of ionosphere and aurora groups. Modifications of this prototype unit design have necessitated a delay in installation but, as indicated in the report on the ionosphere program, installation of all 13 monitors should be completed before September 1957.

Improved instrumentation for photometric observation of the airglow has been developed under the direction of F. E. Roach of CRPL. The new instruments provide for improved spectral and time resolution in observing H-beta, OH, oxygen green and red, and sodium emissions. These instruments have been shipped to the observing sites and those in the lower latitudes are in operation. Those in the higher latitudes will begin operation when the nights become dark enough.

The airglow photoelectric photometers record airglow intensities in the particular spectral regions of interest for a series of specified directions spaced over the sky in elevation and azimuth. The intensity curves obtained are read, and the values are transferred to punch cards which are processed in a computer at Boulder, Colorado, to make necessary corrections to the raw data. The computer prints the data in the form of a sky chart of absolute intensities of emission in a particular spectral region as observed at a given time in the various directions. Data is already being processed in this way.

In the Antarctic, two special programs have been undertaken by IGY observers. At the Pole Station, the patrol spectrograph was mounted on a turntable revolving at one revolution per day for study of the twilight spectrum of the sun. At Ellsworth Station, a special instrument was installed for observations of the H-beta spectral line.

Rocket Program

The experiments described above for the solar activity, ionospheric physics, aurora and airglow, and geomagnetism programs are all to be performed on the ground or from low levels in the atmosphere. The advent of the rocket as a research tool has meant that solar characteristics can be studied without the hindrance of atmospheric screening, and that the high atmosphere itself can be studied with instruments situated within the medium. Thus, the rocket experiments supplement those in the other fields. Observation of the high atmosphere with both ground and rocket-borne instruments has already broadened understanding of the high atmosphere and continues to do so as the IGY program is carried out.

During the IGY, rockets are being used to make observations of pressure, density, and temperature, of color radiation, the ionosphere, atmospheric composition, auroral particles and ultraviolet radiation, and of magnetic fields. These flights will be

launched at latitudes all the way from the Arctic to the Antarctic, but especially at Ft. Churchill, Canada, located in the middle of the auroral zone.

A pre-IGY rocketry program has been carried out over the past year with 24 test flights, including 19 small rockets and 5 Aerobees, in order to perfect techniques and instrumentation.

In the summer and fall of 1956, six Nike-Cajun rockets were instrumented for measurement of atmospheric density by the falling sphere method under the direction of L. M. Jones of the University of Michigan. In this experiment a metal sphere is ejected from the rocket. Telemetered information indicates the deceleration due to atmospheric drag on the sphere, permitting a determination of density. The experiments were sponsored by GRD, of the Air Force Cambridge Research Center, and the National Advisory Committee for Aeronautics. All six flights were successful, the last five having been made from the USS *Rushmore* at sea and attaining more than 100 miles in peak altitude. Data have not yet been reduced.

Two rockets were prepared under N. W. Spencer of the University of Michigan for the measurement of pressure, temperature and density by means of pressure gauges. This work was performed under contract to GRD. The flights were successfully made at Ft. Churchill, attaining altitudes of 70 and 90 miles. Data analyses are not yet completed.

A similar pressure experiment was made in an Aerobee-Hi fired in November 1956 at Ft. Churchill under the supervision of H. E. LaGow of NRL. This flight also carried photon counters prepared by Herbert Friedman and Richard Tousey, of the Optics Division of NRL, for the measurement of soft X-rays and the Lyman alpha line from the sun. From analysis of such altitude-intensity data, atmospheric constituent densities can be determined, but in this experiment the rocket rolled so slowly that the photon counters were presented to the sun too infrequently to obtain reliable results.

Another November flight at Ft. Churchill was instrumented by the University of Michigan for the Signal Corps Engineering Laboratories to obtain temperature and wind data by the exploding-grenade technique. The primary data consist of sound transit times to the ground.

The technique of launching rockets on short notice from balloons already floating at high levels was developed for the study of solar flares. Ten such 'rockoons' were launched in July 1956 by a group under Herbert Friedman, NRL, off the coast of San Diego, California. One flare was detected during these firings. Measurements revealed an X-ray flash extending the spectrum down to nearly 3A and persisting well after the Lyman alpha emission had decayed to normal. At its short wavelength limit it resembled the emission of a four-million-degree thermal source. Although the flare was small the X-ray intensity was theoretically sufficient to produce a substantial increase in D-region electron density between 75 and 85 km. On the basis of the experience gained from this pre-IGY flare experiment it was decided to alter the IGY solar flare firings to utilize the Nike-Deacon combination at Point Mugu, California (San Nicholas Island).

Two pre-IGY launchings were made to determine the distribution of ionospheric charge density by means of radio frequency transmissions between the rocket and ground through the ionosphere. In one experiment, an Aerobee-Hi was launched at Ft. Churchill under the direction of J. E. Jackson of NRL; the experimental technique developed by J. C. Seddon of NRL was used. This experiment was successful although rocket performance was poor. In another experiment to determine electron densities, a Nike-Cajun rocket was instrumented by the US Army Ballistic Research Laboratories under the direction of W. W. Berning and flown at White Sands, New Mexico. This flight was instrumented with the DOVAP system,

and was primarily a test of the suitability of the rocket for such measurements.

Determination of the atmospheric composition at high altitudes is feasible by flying radio-frequency mass spectrometers in rockets. An Aerobee-Hi, instrumented by Edith Meadows and C. Y. Johnson of NRL with three Bennett radio frequency spectrometers, was flown from Ft. Churchill in November 1956. Changes in the ratio of argon to molecular nitrogen, measured by the neutral gas spectrometer, indicated that diffusive separation of the atmospheric gases started between 100 and 110 km. As the rocket rose, peaks of mass numbers 16 and 30 became increasingly important components of the spectra. At 224 km, the highest altitude at which a neutral gas spectrum was obtained, amplitudes of masses 16 (O), 28 (N_2), 30 (NO), and 32 (O_2) differed from each other by less than a factor of 3. The amplitude of 32 was undoubtedly enhanced by the recombination of O atoms on the walls of the inlet tube. Spectra were obtained from a positive ion spectrometer in the mass range 53 to 6 atomic mass units for 375 seconds when the rocket was above 90 km. Mass 30 was the first positive ion detected and remained in the spectra throughout the flight. Positive ions of mass 32 and 16 subsequently appeared. The mass 16 positive ion became the predominant ion with increasing altitude. Two minor positive ions of mass 28 and 18 were detected during the flight. A possible identification of these ions is 32 – O_2^+, 30 – NO^+, 28 – N_2^+, 18 – H_2O^+, 16 – O^+. Above 170 km there was indirect evidence of a positive ion with relatively large abundance at mass 63 ± 2 atomic mass units. A spectral peak in the region of mass 46 was detected by the negative ion spectrometer. Nitric acid, one of the rocket's propellants, might have contributed to some of the ion peaks, although data from the neutral gas spectrometer at the nose of the rocket indicated that the rocket was 'clean.'

Observation of auroral particles and ultraviolet radiation by rocket techniques is an important part of the IGY rocket program. Early information was gained by J. A. Van Allen and his colleagues of the State University of Iowa. Their measurements revealed a 'soft radiation' at altitudes of 40–70 km which exhibited the characteristics of X-rays in the 10–100 kev range. Dr. Van Allen concluded that the X-rays are associated with primary auroral radiations but are not themselves primary in nature. During the IGY, attempts will be made to identify the auroral radiation by means of geiger counters, proportional counters, scintillation counters and energy analyzers. In a pre-IGY firing at Ft. Churchill, photon counter measurements were made of the Lyman alpha intensity and of the spectral band 1220-1350A. Each NRL Aerobee launched at night during the IGY at Ft. Churchill will make such measurements.

Van Allen has adapted a proton precession magnetometer to observe the discontinuity of the earth's field upon traversing the ionospheric current system in small Loki rockets employed with the rockoon technique.

A major accomplishment of the pre-IGY rocket program was the establishment of the Ft. Churchill facility. Not only was a large launching complex installed but numerous instrumentation sites also were erected in the area. The entire rocket program was made possible by the help and cooperation of the US Department of Defense and, additionally, in the case of Ft. Churchill, by the help and cooperation of the Canadian government.

Preprinted from *Transactions, American Geophysical Union*, Vol. 38, No. 5, Oct. 1957